Projected Vegetation and Fire Regime Response to Future Climate Change in Alaska

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**Project Overview**

This project is part of a statewide model analysis of future vegetation and fire regime response to projected future climate. This work is supported by grants from the National Science Foundation and the Joint Fire Science Program. Additional support has been provided by the UA Scenarios Network for Alaska Planning (SNAP) initiative and from the University of Alaska Fairbanks, US Fish and Wildlife Service, and the National Park Service.

This document provides a summary of preliminary simulation results and a discussion of ongoing modeling activities aimed at providing definitive statewide simulation results. In addition, simulation model details and references are included.

**Model Simulations Design**

The model simulations design (Fig. 1) provides for the analysis of historical fire activity by (1) simulating historic fires (1860-2007) based on an empirically derived relationship between climate and fire (Duffy et al. 2005), and (2) linking simulated historic fires (1860-1949), based on the empirical climate-fire relationship, with known fire perimeters (1950-2007; http://agdc.usgs.gov/data/blm/fire/index.html). The historical simulation results for both methodologies will then be applied to a suite of 6 future climate scenarios (2008-2099) and three emission scenarios (A1B, A1, and B2; see IPCC 2007). This report presents preliminary results for only the A1B emission scenario.

![Figure 1 – Schematic showing the model simulation design.](image-url)
The simulation design ultimately allows for statewide simulations (Fig. 2) of both historical simulation methodologies (2x) to be driven by 6 future climate scenarios (6x) for each of 3 emissions scenarios (3x) for a total of 36 (2x6x3) ensemble runs. Each preliminary ensemble run contains 8 replicated simulations (30 replications to be completed in the final analysis). In all simulations historic climate (1860-2002) was generated using spatially explicit input data from the Climate Research Unit (CRU; http://www.cru.uea.ac.uk/) and the Potsdam Institute for Climate Impact Research (PICIR). The PICAR dataset is a modified version of that presented in Leemans and Cramer (1991). The modification is presented in McGuire et al. (2001).

The ‘spin-up’ phase of the modeling generated 30 different initial landscape conditions (vegetation distribution and age structure) at 1860 by using 30 random permutations of historic climate observations from the CRU and PICIR datasets. These landscapes provide the starting-point (1860) conditions that ALFRESCO uses as input for the simulations. The purpose of the ‘spin-up’ phase is to produce a simulation landscape with realistic patch size and age-class distributions that are generated over multiple fire cycles.

Figure 2 – Statewide simulation domain with refuge boundaries identified.
ALFRESCO Model Overview

ALFRESCO was originally developed to simulate the response of subarctic vegetation to a changing climate and disturbance regime (Rupp et al. 2000a, 2000b). Previous research has highlighted both direct and indirect (through changes in fire regime) effects of climate on the expansion rate, species composition, and extent of treeline in Alaska (Rupp et al. 2000b, 2001, Lloyd et al. 2003). Additional research, focused on boreal forest vegetation dynamics, has emphasized that fire frequency changes – both direct (climate-driven or anthropogenic) and indirect (as a result of vegetation succession and species composition) – strongly influence landscape-level vegetation patterns and associated feedbacks to future fire regime (Rupp et al. 2002, Chapin et al. 2003, Turner et al. 2003). A detailed description of ALFRESCO can be obtained from the literature (Rupp et al. 2000a, 2000b, 2001, 2002). The boreal forest version of ALFRESCO was developed to explore the interactions and feedbacks between fire, climate, and vegetation in interior Alaska (Rupp et al. 2002, 2007, Duffy et al. 2005, 2007) and associated impacts to natural resources (Rupp et al. 2006, Butler et al. 2007).

ALFRESCO is a state-and-transition model of successional dynamics that explicitly represents the spatial processes of fire and vegetation recruitment across the landscape (Fig. 3; Rupp et al. 2000a). ALFRESCO does not model fire behavior, but rather models the empirical relationship between growing-season climate (e.g., average temperature and total precipitation) and total annual area burned (i.e., the footprint of fire on the landscape). ALFRESCO also models the changes in vegetation flammability that occur during succession through a flammability coefficient that changes with vegetation type and stand age (Chapin et al. 2003).

The fire regime is simulated stochastically and is driven by climate, vegetation type, and time since last fire (Rupp et al. 2000a, 2007). ALFRESCO employs a cellular automaton approach, where an ignited pixel may spread to any of the eight surrounding pixels. ‘Ignition’ of a pixel is determined using a random number generator and as a function of the flammability value of that pixel. Fire ‘spread’ depends on the flammability of the receptor pixel and any effects of natural firebreaks including non-vegetated mountain slopes and large water bodies, which do not burn.

The ecosystem types modeled were chosen as the simplest possible representation of the complex vegetation mosaic occupying the circumpolar arctic and boreal zones and ignore the substantial variation in species composition within these and other intermediate vegetation types. Detailed descriptions of the vegetation states and classification methodology can be found in Rupp et al. (2000a, 2000b, 2001, 2002). The vegetation data used in the model spinup process was derived by reclassifying the 1990 AVHRR vegetation classification (http://agdcftp1.wr.usgs.gov/pub/projects/fhm/vegcls.tar.gz) and the 2001 National Land Cover Database vegetation classification (http://www.mrlc.gov) into the five vegetation classes represented in ALFRESCO (tundra, black spruce, white spruce, deciduous, and dry grassland). Currently, the dry grassland ecosystem type represented in ALFRESCO occurs only locally and at a scale masked by the model’s 1 x 1 km pixel resolution. Differences among tundra vegetation types recognized in the vegetation classifications were ignored, and all tundra types were lumped together as a single tundra class. Tundra types that identified some level of spruce canopy on site were indicated. The actual spruce-canopy level was determined using growing-season climate thresholds.
Remotely sensed satellite data is currently unable to distinguish species-level differences between black and white spruce. We therefore stratified spruce forest using deterministic rules related to topography (i.e., aspect, slope position, and elevation) and growing-season climate. Aspect and slope were used to identify ‘typical’ black spruce forest sites (i.e., poorly drained and northerly aspects) throughout the study region. Growing-season climate and elevation were used primarily to distinguish treeline white spruce forest. In addition, we used growing-season climate thresholds to distinguish young deciduous forest stands from tall shrub tundra. These deterministic rules were also used to denote the climax vegetation state (i.e., black or white spruce forest) for each deciduous pixel. In other words, the rules were used to predetermine the successional trajectory of each deciduous pixel. In this manner, we were able to develop an input vegetation data set that best related the original remotely sensed data into the five vegetation types represented by ALFRESCO, based on a sensible ecological foundation.

**Figure 3 – Conceptual model of vegetation states (colored boxes), possible transitions (arrows), and driving processes/factors responsible for the rate and direction of transitions (arrow labels). Dynamic treeline transitions and the dry grassland state were not activated for the preliminary simulations.**

Version 1.0.1 can operate at any time step and pixel resolution, however the current model calibration and parameterization was conducted at an annual time step and 1 km² pixel resolution. A 30 m² calibration and parameterization is currently underway. Other model developments include refined tundra transition stages, fire suppression effects on fire size, simulated fire severity patterns and fire severity effects on successional rates and trajectories. New iterations of the boreal ALFRESCO simulation model with these developments will be available beginning in 2009.
Driving Climate Products

The simulation design for this project utilizes climate projections that have been assessed and downscaled by the UA Scenarios Network for Alaska Planning (SNAP).

Use of GCMs to model future climate

General Circulation Models (GCMs) are the most widely used tools for projections of global climate change over the timescale of a century. Periodic assessments by the Intergovernmental Panel on Climate Change (IPCC) have relied heavily on global model simulations of future climate driven by various emission scenarios.

The IPCC uses complex coupled atmospheric and oceanic GCMs. These models integrate multiple equations, typically including surface pressure; horizontal layered components of fluid velocity and temperature; solar short wave radiation and terrestrial infra-red and long wave radiation; convection; land surface processes; albedo; hydrology; cloud cover; and sea ice dynamics.

GCMs include equations that are iterated over a series of discrete time steps as well as equations that are evaluated simultaneously. Anthropogenic inputs such as changes in atmospheric greenhouse gases can be incorporated into stepped equations. Thus, GCMs can be used to simulate the changes that may occur over long time frames due to the release of greenhouse gases into the atmosphere.

Greenhouse gas-driven climate change represents a response to the radiative forcing associated with increases of carbon dioxide, methane, water vapor and other gases, as well as associated changes in cloudiness. The response varies widely among models because it is strongly modified by feedbacks involving clouds, the cryosphere, water vapor and other processes whose effects are not well understood. Changes in the radiative forcing associated with increasing greenhouse gases have thus far been small relative to existing seasonal cycles. Thus, the ability of a model to accurately replicate seasonal radiative forcing is a good test of its ability to predict anthropogenic radiative forcing.

Model Selection

Different coupled GCMs have different strengths and weaknesses, and some can be expected to perform better than others for northern regions of the globe.

SNAP principle investigator Dr. John Walsh and colleagues evaluated the performance of a set of fifteen global climate models used in the Coupled Model Intercomparison Project. Using the outputs for the A1B (intermediate) climate change scenario, they calculated the degree to which each model’s output concurred with actual climate data for the years 1958-2000 for each of three climatic variables (surface air temperature, air pressure at sea level, and precipitation) for three overlapping regions (Alaska only, 60-90 degrees north latitude, and 20-90 degrees north latitude.)

The core statistic of the validation was a root-mean-square error (RMSE) evaluation of the differences between mean model output for each grid point and calendar month, and data from the European Centre for Medium-Range Weather Forecasts (ECMWF) Re-Analysis, ERA-40. The ERA-40 directly assimilates observed air temperature and sea level pressure observations into a product spanning 1958-2000. Precipitation is
computed by the model used in the data assimilation. The ERA-40 is one of the most consistent and accurate gridded representations of these variables available.

To facilitate GCM intercomparison and validation against the ERA-40 data, all monthly fields of GCM temperature, precipitation and sea level pressure were interpolated to the common 2.5° × 2.5° latitude–longitude ERA-40 grid. For each model, Walsh and colleagues calculated RMSEs for each month, each climatic feature, and each region, then added the 108 resulting values (12 months x 3 features x 3 regions) to create a composite score for each model (Table 1). A lower score indicated better model performance.

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Table 1 – Component and overall ranking of the 15 GCMs evaluated from the IPCC 4th assessment. The top five models were chosen as performing best over Alaska.

The specific models that performed best over the larger domains tended to be the ones that performed best over Alaska. Although biases in the annual mean of each model typically accounted for about half of the models' RMSEs, the systematic errors differed considerably among the models. There was a tendency for the models with the smaller errors to simulate a larger greenhouse warming over the Arctic, as well as larger increases of Arctic precipitation and decreases of Arctic sea level pressure when greenhouse gas concentrations are increased.

Since several models had substantially smaller systematic errors than the other models, the differences in greenhouse projections implied that the choice of a subset of models might offer a viable approach to narrowing the uncertainty and obtaining more robust estimates of future climate change in regions such as Alaska. Thus, SNAP selected the five best-performing models out of the fifteen: MPI_ECHAM5, GFDL_CM2_1, MIROC3_2_MEDRES, UKMO_HADCM3, and CCCMA_CGCM3_1. These five models are used to generate climate projections independently, as well as in combination (i.e.,
composite), in order to further reduce the error associated with dependence on a single model.

**Downscaling model outputs**

Because of the mathematical complexity of GCMs, they generally provide only large-scale output, with grid cells typically 1°-5° latitude and longitude. For example, the standard resolution of HadCM3 is 1.25 degrees in latitude and longitude, with 20 vertical levels, leading to approximately 1,500,000 variables.

Finer scale projections of future conditions are not directly available. However, local topography can have profound effects on climate at much finer scales, and almost all land management decisions are made at much finer scales. Thus, some form of downscaling is necessary in order to make GCMs useful tools for regional climate change planning.

Historical climate data estimates at 2 km resolution are available from PRISM (Parameter-elevation Regressions on Independent Slopes Model), which was originally developed to address the lack of climate observations in mountainous regions or rural areas. PRISM uses point measurements of climate data and a digital elevation model to generate estimates of annual, monthly and event-based climatic elements. Climatic elements for each grid cell are estimated via multiple regression using data from many nearby climate stations. Stations are weighted based on distance, elevation, vertical layer, topographic facet, and coastal proximity.

PRISM offers data at a fine scale that is useful to land managers and communities, but it does not offer climate projections. Thus, SNAP needed to link PRISM to the GCM outputs. This work was also performed by PI Walsh and colleagues. They first calculated mean monthly precipitation and mean monthly surface air temperature for PRISM grid cells for 1961-1990, creating PRISM baseline values. Next, they calculated GCM baseline values for each of the five selected models using mean monthly outputs for 1961-1990. They then calculated differences between projected GCM values and baseline GCM values for each year out to 2099 and created “anomaly grids” representing these differences. Finally, they added these anomaly grids to PRISM baseline values, thus creating fine-scale (2 km) grids for monthly mean temperature and precipitation for every year out to 2099. This method effectively removed model biases while scaling down the GCM projections.

**Statewide Driving Climate Summary**

Climate data can soon be accessed through SNAP (www.snap.uaf.edu) in tabular form, as graphs, or as maps (GIS layers and KML files) depicting the whole state of Alaska or part of the state. Currently, tables or graphs of mean monthly temperature and precipitation projections by decade are available for 353 communities in Alaska. Statewide GIS layers of mean monthly temperature and total precipitation for each year out to 2099 are also currently available and were used to develop the input data sets used in this project.

The following time series graphs and maps provide examples of the types of summary information that can be generated for any defined region within the state.
Figure 4 – Time series of average March thru June temperature (C°) integrated across the statewide simulation domain for the historical climate (CRU), the five downscaled GCMs, and the composite GCM.

Figure 5 – Map of average June temperature (C°) for the composite GCM model. Historical (1971-2000) is CRU data at 0.5 x 0.5 degree resolution. Downscaled data at 2 x 2 km resolution averaged over two future time periods.
Figure 6 – Map of average June temperature (°C) for the composite GCM model. Historical (1971-2000) is CRU data at 0.5 x 0.5 degree resolution. Downscaled data at 2 x 2 km resolution averaged over two future time periods.
Model Simulation Results

The results presented here represent preliminary results. Although we are confident in the overall statewide simulations and their trends, there are several additional refinements that are currently underway. These refinements will be discussed within the report. Final simulation results that incorporate these refinements will be presented in a peer-reviewed journal article scheduled to be submitted summer 2008.

Empirical Climate-Fire Relationship

The ALFRESCO model was driven by spatially explicit datasets of observed and projected monthly temperature and precipitation (see Model Simulation Design section) – March through June monthly average temperature and June and July total precipitation. Based on future projections we expect climatic effects alone to result in substantial increases (as much as 50%) in landscape flammability across all 5 climate scenarios (Fig. 7).

Figure 7 – Time series showing climatic influence on landscape flammability across all vegetation types. CRU observational data (black circles) and the composite future climate (yellow circles); ECHAM5 (red dashed line) represents the greatest warming scenario; CGCM3.1 (purple dashed line) represents the least warming scenario. Black dashed line is 10-yr running average.

One factor that may potentially confound the interpretation of these future results is the potential for the boreal forest ecosystem to dramatically change. For example, one of the likely consequences of future climate change appears to be a significant increase in the amount of burning. This elevated burning results in a shift from conifer dominance to deciduous dominance across interior Alaska. Since the regression linking climate to fire was developed based on a forest structure that was dominated by coniferous vegetation, it is likely that the form of this relationship will change following a shift in the dominant forest vegetation type. This shift will take several decades to develop and one
way to mitigate this impact is to periodically revise the model linking climate and fire. We are currently working on characterizing changes in this linkage between climate and fire through time. One of the limiting factors for this type of analysis is the limited amount of data that are available to explore these changes through time. However, we are moving forward using the available data to characterize and implement potential changes in the linkage between climate and fire that essentially represent a feedback between the forest structure and the climate-fire linkage. Overall, these impacts will be greatest for the latter half of the future simulation period (2050-2099). Given that it will likely take at least several decades for these changes in the structure of the forest to take effect, we feel confident that this current set of ALFRESCO simulation output realistically depicts the average landscape response to each of the down-scaled IPCC climate scenarios.

**Historical Simulations**

The preliminary results presented in this report cover only simulated historic fires (1860-2007) based on an empirically derived relationship between climate and fire (Duffy et al. 2005; see Empirical Climate-Fire Relationship section). The ALFRESCO model performed well simulating historical landscape dynamics that closely followed observed fire regime and vegetation cover characteristics. This assessment is made based on a number of different calibration metrics that compare simulated data to various aspects of the fire regime (e.g. fire size distribution, frequency-area distribution, cumulative area burned). Cumulative area burned is consistent with observed area burned from 1950-2007 (Fig. 8). In general, ALFRESCO underestimates cumulative area burned. Differences in simulated and observed cumulative area burned occur primarily because (1) we are unable to accurately simulate the 1950 fire season, and (2) ALFRESCO simulated fire perimeters contain inclusions of unburned areas whereas the observed fire perimeters disregard inclusions.

![Figure 8 – Comparison of historical (black line) and simulated (blue line) cumulative area burned (km²) from 1950-2007. Solid blue line represents mean (x=8) and the dashed blue lines represent individual replicate results.](image-url)
The individual replicate simulations also captured well the interannual variability in total area burned (Fig. 9) and the spatial distribution of fires across the landscape (Fig. 10). ALFRESCO performed well simulating fire activity from 1860-1949 relative to the statistically backcast estimates. These backcast estimates were generated by taking the statistical model linking climate and fire and applying it to historical data. The validity of this backcast is dependent on the relative stability of the structure of the boreal forest from 1859-2007; however, there is currently no strong evidence suggesting that the vegetation dynamics of the boreal forest in Alaska have been radically altered from 1859-2007. Although the model performed well overall, correlations ranged from 0.51-0.58, simulating observed historical fire activity (1950-2007), ALFRESCO performed better over the second half of the observation period.

![Figure 9](image_url)

*Figure 9 – Historical observed (orange boxes) and statistical backcast (green boxes) versus simulated (red circles) total annual area burned. Simulation results from the best single replicate (replicate 6).*
Figure 10 – Map showing observed fire perimeters (left panel) and simulated fire perimeters (right panel). Color scale indicates time since last fire (darker red equals more recent fires). Simulated results from the best single replicate (replicate 6). The four regions identified by black outlines identify major ecoregion delineations.

We parameterized the model using major ecoregion delineations (Fig. 10) to account for the distinct differences in observed fire history between the North Slope, Seward Peninsula, interior Alaska, and southcentral Alaska; each ecoregion has a different set of fire-climate-vegetation parameters developed during the calibration phase of the simulations.

Currently, we hold the most confidence in the simulation results for the interior Alaska region. We are in the process of further development and refinement of the tundra vegetation state, which will increase our confidence in the North Slope and Seward Peninsula regions. Further development and implementation of the grassland frame in southcentral Alaska will also improve our confidence in the simulation results. Interpretation of the simulation results should consider two major sources of uncertainty: (1) the GCM projections and validity of ALFRESCO model assumptions regarding successional trajectories become less certain the farther into the future we consider, and (2) due to the stochastic nature of ALFRESCO it is not possible to simulate the exact geographic location of future fire occurrence or vegetation type.

The ALFRESCO model also performed well simulating general vegetation composition across the landscape. Model simulations suggest a long-term dominance of conifer forest relative to deciduous vegetation (Fig. 11). However, since approximately 1990 the difference in proportion of conifer to deciduous has decreased substantially as a direct result of increased fire activity and conversion of conifer forest to early successional deciduous vegetation. Remotely sensed data provides two snapshots in time, 1990 and 2001, from which we can directly compare proportion of conifer to deciduous. At both time slices ALFRESCO was consistent (1990 observed ratio = 2.3 versus 1990 average (x=8) simulated ratio = 1.6; 2001 observed ratio = 1.5 versus 2001 average (x=8) simulated ratio = 1.5) with the classified remote sensing data (Fig. 11 and Fig. 12).
Figure 11 – Time series showing the total simulated amount of conifer (green line) versus deciduous (brown line) vegetation 1860-2007 across interior Alaska. AVHRR classification (http://agdcftp1.wr.usgs.gov/pub/projects/fhm/vegcls.tar.gz) at 1990 and the National Land Cover Database (http://www.mrlc.gov) at 2001.

Figure 12 – Vegetation map from a single replicate showing the simulated distribution of vegetation types across the landscape.
**Future Projections**

The success of ALFRESCO in simulating historical observations when driven with historical climate provides a degree of confidence that allows us to simulate into the future, driving the simulations with projected climate scenarios, and to use that information to make inferences about future landscape structure and function.

ALFRESCO simulations suggest in general an increase in cumulative area burned through 2099 (Fig. 13). Changes in the slope of cumulative area burned suggest that the next 20-30 years will likely produce rapid change in fire activity and subsequent landscape dynamics. However, individual climate scenarios produced substantial differences in simulated fire activity. ECHAM5 and MIROC3.5 GCM scenarios produced the largest simulated changes in fire activity, whereas GFDL2.1 and HADCM3 produced more moderate simulated fire activity. CGCM3.1 produced the least simulated future fire activity. Individual replicate simulations also identify continued interannual variability in total area burned, but with less frequent periods of low fire activity (Figs. 14-16).

![Graph showing simulated cumulative area burned through 2099](image)

*Figure 13 – Time series graph showing simulated cumulative area burned (km$^2$) through 2099 for historical observations (black line), simulated historical (dark green line), and the five GCM scenarios plus the composite scenario (also dark green line).*
Figure 14 – Time series graph showing simulated fire activity for a single replicate simulation of the ECHAM5 climate scenario. The ECHAM5 climate scenario produced the largest increase in fire activity.

Figure 15 – Time series graph showing simulated fire activity for a single replicate simulation of the CGCM3.1 climate scenario. The CGCM3.1 climate scenario produced the smallest increase in fire activity.
The simulated response of vegetation to increased burning suggests the potential for a substantial shift in the future proportion of conifer and deciduous forest on the landscape (Fig. 17). Although there is variability in the simulated response of vegetation across climate scenarios all scenarios simulate a shift in dominance. The magnitude of the shift differs from the most warming scenario (ECHAM5; Fig. 18 and 19) to the least warming scenario (CGCM3.1; Fig. 20 and Fig. 21).
Figure 18 – Time series for the ECHAM5 climate scenario showing the total simulated amount of conifer (green line) versus deciduous (brown line) vegetation 1860-2099 across interior Alaska.

Figure 19 – Vegetation map from a single replicate of the ECHAM5 climate scenario showing the simulated distribution of vegetation types across the landscape.
Figure 20 – Time series for the CGCM3.1 climate scenario showing the total simulated amount of conifer (green line) versus deciduous (brown line) vegetation 1860-2099 across interior Alaska.

Figure 21 – Vegetation map from a single replicate of the CGCM3.1 climate scenario showing the simulated distribution of vegetation types across the landscape.
Summary of Preliminary Simulation Results and Management Implications

Preliminary results from the statewide simulations identify consistent trends in projected future fire activity and vegetation response. The simulation results strongly suggest that boreal forest vegetation will change dramatically from the spruce dominated landscapes of the last century. While Figures 17 through 21 identify a range of potential responses between the different climate scenarios, all model results show a shift in landscape dominance from conifer to deciduous vegetation within the next 50 years.

The ALFRESCO model simulations suggest a general increase in fire activity through the end of this century (2099) in response to projected warming temperatures and less available moisture. Changes in the projected cumulative area burned suggest the next 20-30 years will experience the most rapid change in fire activity and the associated changes in vegetation dynamics. Future fire activity suggests more frequent large fire seasons and a decrease in magnitude and periodicity of small fire seasons. Large differences do exist among climate scenarios providing multiple possible futures that must be considered within the context of land and natural resource management.

Increased deciduous dominance on the landscape will contribute to a probable change in the patch dynamics between vegetation types and age. The large regions of mature unburned spruce will likely be replaced by a more patchy distribution of deciduous forests and younger stages of spruce. The simulation results suggest that this change will occur over the next few decades, in response to simulated increases in fire activity, and will then reach an equilibrium stage where the patch dynamics may self-perpetuate for many decades if not centuries. In spite of the shift towards less flammable age classes and towards deciduous species, the simulation results indicate that there will be more frequent fires burning; resulting in an overall increase in acres burned annually. These two results appear to drive the simulated change in landscape dynamics where increased landscape flammability, driven by climate change, modifies landscape-level vegetation (i.e., fuels) distribution and pattern, which in turn feeds back to future fire activity by reducing vegetation patch size (i.e., fuel continuity).

Decisions made by fire and land managers during this current period of rapid change, will influence the structure and pattern of vegetation across the boreal forest in Alaska. Fire managers should consider how land management objectives may be affected by the predicted changes to natural fire on the landscape. The Boreal ALFRESCO model can be used to simulate how changes in fire management may change the potential future landscape, it can also be used to assess how particular vegetation age classes (i.e., deciduous forest 10-30 years old) that may represent habitat conditions for important wildlife resources may be affected by the fire, vegetation and climate interactions predicted into the future.

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ALFRESCO Model References


